# Dialysis and kidney transplantation among patients living in rural areas of the United States

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**Although one-fifth of the United States population is rural, little is known about the characteristics and outcomes of rural dialysis patients. We measured the association of rural residence with patient characteristics, survival, and time to transplant among 552 279 patients who initiated dialysis between January 1, 1995 and December 31, 2002 and survived more than 90 days. We also examined the characteristics of 4363 Medicare-certified dialysis facilities by degree of rurality. Compared with urban patients, rural dialysis patients were older, less racially diverse with a higher prevalence of most co-morbid conditions. Hemodialysis was the dominant modality in both urban and rural areas, although the use of peritoneal dialysis was more frequent in rural areas. Survival and time to transplant differed by racial–ethnic group. Most notably, despite slightly better survival associated with rural vs urban residence among black popultions, black populations living in rural areas were less likely to be transplanted than their urban counterparts (and than any other group examined). Compared with urban facilities, rural facilities are smaller, less likely to be for profit or owned by a large chain. Nonetheless, rural facilities perform at least as well as urban facilities based on standard performance measures. Despite more frequent use of peritoneal dialysis among rural patients, rural facilities were markedly less likely to offer peritoneal dialysis or home hemodialysis training than urban facilities. Rural black patients (most of whom live in the south) should be targeted in policies to reduce racial disparities in access to transplant. Further studies are needed to determine whether rural dialysis patients have adequate access to home-based therapies.**

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Approximately 20% of the United States (US) population lives in rural areas. Recently, the quality of healthcare in rural America has been the focus of several prominent reports (http://www.medpac.gov/publications/congressional_testimony/Tst061201W&M_Rural.pdf;[1,2]). However, the care of dialysis patients, a large and expanding portion of the Medicare budget, was not addressed in these reports.[3,4] Although little has been published on dialysis care in rural areas, the quality of services that might be relevant to this group, such as cardiac care and provision of emergency medical services, may be worse in rural than in urban areas in the US.[2,5] Furthermore, dialysis care requires a greater intensity of provider contact than most other forms of outpatient care, leading us to hypothesize that the structure and quality of dialysis care would be substantially different and patient outcomes worse in rural compared with urban areas.

## RESULTS

Among the 552 279 incident dialysis patients studied, 431 203 (78%) lived in an urban area, 49 565 (9%) lived in a large rural area, 41 494 (8%) lived in a small rural area, and 30 017 (5%) lived in a remote small rural area 90 days after starting chronic dialysis. While non-Hispanic white cohort patients were found in all regions of the country, there were strong regional patterns to the distribution of other racial/ethnic groups and, in some instances, these distributions differed for urban and rural populations (Figure 1). For example, urban black patients were concentrated in the South, Midwest, and Northeast, whereas rural black patients were concentrated in the South. With increasing rurality, patients were older, the percentage of Asian and black patients was lower, and the percentage of Native American and white patients was higher (Table 1). The prevalence of most comorbidities increased across the urban–rural spectrum. In both rural and urban locations, most patients were receiving in-center hemodialysis at the time of cohort entry. However, the percentage receiving peritoneal dialysis was higher in rural areas. Less than 0.5% of patients in both urban and rural areas were receiving home hemodialysis.

The impact of rural residence on overall patient survival varied by racial/ethnic group ($P$ for interaction $<0.001$). The impact of rural residence on crude annual mortality rates was much less striking than the impact of racial/ethnic group, with much higher mortality rates noted among non-Hispanic white patients compared with all other groups across the rural urban spectrum (Figure 2). In unadjusted analysis, survival did not differ significantly across the urban–rural spectrum for all but Hispanic white patients in whom mortality was higher in rural than in urban areas (Table 2). After adjustment for demographic characteristics, comorbid conditions and zip code median per capita income and percentage of high school graduates, rural non-Hispanic white, and black patients had slightly better survival than their urban counterparts, whereas Hispanic patients living in remote small rural areas had worse survival than urban Hispanic white patients. For Asian and Native American patients, there were no statistically significant differences in survival across the urban–rural spectrum.

Transplant rates were consistently lowest for black patients and highest for non-Hispanic white patients regardless of urban–rural location. However, while rates among white patients differed little by location, rates among black and Native American patients were lowest in small rural areas (Figure 3). In unadjusted analysis, time to transplant was no different in rural than in urban areas for white non-Hispanic, white Hispanic, and Asian patients (Table 3). Unadjusted time to transplant was longer for black and Native American patients living in rural compared with urban areas, with lowest rates occurring in small rural areas. After adjustment for demographic characteristics, comorbid conditions, and zip code socioeconomic indicators, white non-Hispanic, patients living in rural areas and Native American patients living in remote small rural areas were more likely to undergo transplantation than those living in urban areas, whereas

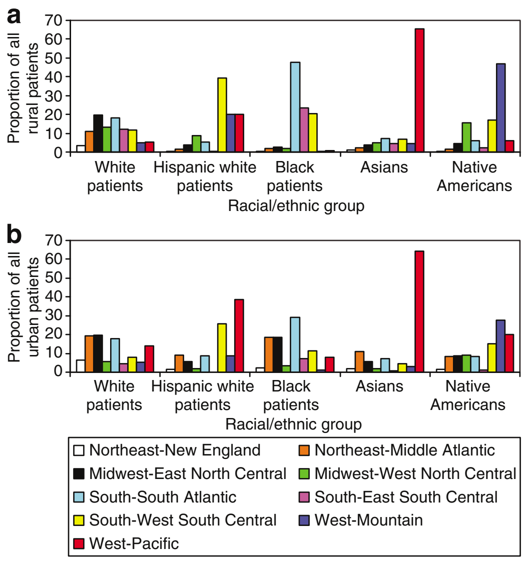


**Figure 1 | Regional location of (a) rural dialysis patients. (b)** Urban dialysis patients by racial/ethnic group.

**Table 1 | Patient characteristics by degree of rurality of residential area**

| | Urban (431 203) | Large rural (49 565) | Small rural (41 494) | Small remote rural (30 017) |
|---|---|---|---|---|
| Age (mean ± s.d.) | 61 ± 16 | 61 ± 16 | 62 ± 16 | 62 ± 15 |
| *Race (%)* | | | | |
| Non-Hispanic white | 49 | 64 | 64 | 70 |
| Hispanic white | 11 | 8 | 6 | 4 |
| Black | 33 | 24 | 25 | 19 |
| Asian | 4 | 2 | 0.7 | 0.6 |
| Native American | 0.7 | 2 | 4 | 6 |
| Other | 2 | 0.6 | 0.4 | 0.3 |
| Female (%) | 46 | 48 | 48 | 46 |
| Diabetes (%) | 47 | 51 | 51 | 51 |
| Cardiac disease (%) | 40 | 45 | 45 | 46 |
| Peripheral arterial disease (%) | 13 | 16 | 16 | 16 |
| Smoking (%) | 5 | 7 | 7 | 7 |
| Stroke (%) | 8 | 10 | 9 | 10 |
| *Modality at day 90 (%)* | | | | |
| Center hemodialysis | 88 | 86 | 84 | 83 |
| Peritoneal dialysis | 11 | 13 | 15 | 17 |
| Home hemodialysis | 0.13 | 0.15 | 0.11 | 0.19 |
| Unknown | 0.50 | 0.33 | 0.37 | 0.51 |
| Median zip code per capita income in dollars, (25th–75th percentile range) | 20 595 (16 706, 26 110) | 16 682 (14 680, 18 924) | 15 945 (13 922, 16 154) | 15 768 (13 663, 17 757) |
| Mean percent zip code residents > 25 years with high school diploma, ± s.d. | 81 ± 12 | 77 ± 11 | 74 ± 11 | 75 ± 11 |

black patients living in large and small rural areas were less likely to undergo transplantation. For both survival and time to transplant, analyses based on time from date of first end-stage renal disease (ESRD) service rather than time from day 91 did not differ materially from the primary analyses.

At the facility level, in both urban and rural areas, most dialysis facilities were for profit and owned by large chains (Table 4). However, the percentage of nonprofit and independent units was higher in rural than in urban areas. Rural units were on average smaller than urban units and less likely to offer a late shift of dialysis. The percentage of units offering peritoneal dialysis and home hemodialysis training decreased markedly from urban to rural areas. The percentages of patients reaching target hematocrit levels were similar for rural and urban facilities; the percentages reaching target urea reduction ratios were higher in rural than urban facilities and fewer rural than urban facilities had worse than expected patient survival.

## DISCUSSION

More than 20% of incident dialysis patients and almost one-third of dialysis facilities in the US are located in a rural area. Despite differences in the structure of dialysis care in rural areas (fewer for-profit facilities, fewer small chains, smaller dialysis facilities, fewer units offering peritoneal dialysis or home hemodialysis training), rural dialysis facilities performed at least as well (if not better) than urban facilities on several quality measures. While we had hypothesized that patient outcomes would be worse in rural areas compared with urban areas, the association of rural residence with patient survival and time to transplant was far more complex than we had originally imagined. In general, racial/ethnic group was a much stronger determinant of patient survival than rural residence: with much higher mortality rates in white non-Hispanic patients than in any other racial/ethnic group across the urban–rural spectrum. Nonetheless, there were some urban–rural differences in survival within groups: black and non-Hispanic white patients living in rural areas had slightly lower mortality than their urban counterparts. Hispanic white patients living in remote small rural areas had higher mortality than urban Hispanics. Asian and Native American patients had similar survival across the urban–rural spectrum. Rural residence had a more sizeable impact on time to transplantation. While transplant rates were highest for non-Hispanic white patients and lowest for black patients across the urban–rural spectrum, the gap between these two

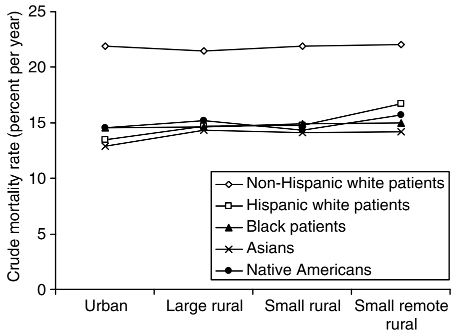


**Figure 2 | Unadjusted mortality rate by racial/ethnic group.**

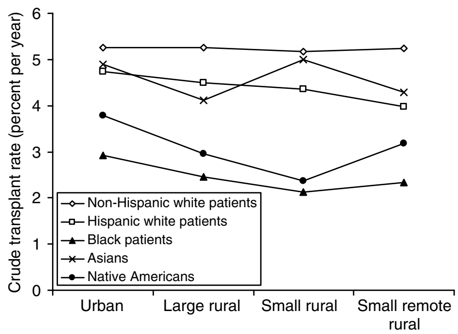


**Figure 3 | Unadjusted transplant rate by racial/ethnic group.**

**Table 2 | Survival by degree of rurality, after stratification by race and ethnicity**

| Racial/ethnic group | Location: Urban (*n*=431 203) | Large rural (*n*=49 565) | Small rural (*n*=41 494) | Remote small rural (*n*=30 017) |
|---|---|---|---|---|
| | | Unadjusted results | | |
| White non-Hispanic (*n*=290 445) | 1.00 (referent) | 0.98 (0.97, 1.00) | 1.00 (0.99, 1.02) | 1.01 (0.99, 1.03) |
| White Hispanic (*n*=56 087) | 1.00 (referent) | 1.10 (1.04, 1.15) | 1.10 (1.03, 1.17) | 1.25 (1.14, 1.36) |
| Black (*n*=171 329) | 1.00 (referent) | 1.00 (0.98, 1.03) | 1.02 (0.99, 1.05) | 1.03 (0.98, 1.07) |
| Asian (*n*=19 638) | 1.00 (referent) | 1.11 (0.99, 1.24) | 1.10 (0.92, 1.31) | 1.10 (0.88, 1.36) |
| Native American (*n*=7554) | 1.00 (referent) | 1.05 (0.94, 1.16) | 0.98 (0.90, 1.07) | 1.08 (0.99, 1.18) |
| | | Adjusted results | | |
| White non-Hispanic (*n*=290 445) | 1.00 (referent) | 0.97 (0.95, 0.98) | 0.98 (0.96, 0.99) | 0.94 (0.92, 0.96) |
| White Hispanic (*n*=56 087) | 1.00 (referent) | 1.02 (0.97, 1.07) | 1.02 (0.96, 1.09) | 1.11 (1.01, 1.22) |
| Black (*n*=171 329) | 1.00 (referent) | 0.97 (0.94, 1.00) | 0.94 (0.91, 0.97) | 0.93 (0.90, 0.97) |
| Asian (*n*=19 638) | 1.00 (referent) | 1.06 (0.95, 1.19) | 1.12 (0.93, 1.15) | 1.00 (0.79, 1.26) |
| Native American (*n*=7554) | 1.00 (referent) | 0.97 (0.86, 1.08) | 0.96 (0.87, 1.06) | 1.02 (0.92, 1.13) |

Hazard ratio (95% confidence interval), adjusted for age, gender, diabetes, cardiac disease, peripheral vascular disease, stroke, smoking at the initiation of dialysis, modality at 90 days, and zip code median per capita income and percent residents >25 years with a high school diploma.

**Table 3 | Time to first kidney transplant by degree of rurality and racial/ethnic group**

| Racial/ethnic group | Urban (*n*=431 203) | Large rural (*n*=49 565) | Small rural (*n*=41 494) | Remote small rural (*n*=30 017) |
|---|---|---|---|---|
| | | | Unadjusted results | |
| White non-Hispanic (*n*=290 445) | 1.00 (referent) | 1.00 (0.96, 1.03) | 0.98 (0.95, 1.02) | 1.00 (0.96, 1.04) |
| White Hispanic (*n*=56 087) | 1.00 (referent) | 0.95 (0.87, 1.04) | 0.92 (0.82, 1.03) | 0.85 (0.70, 1.02) |
| Black (*n*=171 329) | 1.00 (referent) | 0.84 (0.78, 0.90) | 0.73 (0.67, 0.79) | 0.80 (0.72, 0.88) |
| Asian (*n*=19 638) | 1.00 (referent) | 0.85 (0.68, 1.05) | 1.03 (0.75, 1.43) | 0.88 (0.58, 1.34) |
| Native American (*n*=7554) | 1.00 (referent) | 0.78 (0.61, 1.00) | 0.62 (0.50, 0.76) | 0.85 (0.70, 1.02) |
| | | | Adjusted results | |
| White non-Hispanic (*n*=290 445) | 1.00 (referent) | 1.06 (1.02, 1.10) | 1.09 (1.05, 1.14) | 1.11 (1.06, 1.16) |
| White Hispanic (*n*=56 087) | 1.00 (referent) | 1.06 (0.96, 1.17) | 1.07 (0.95, 1.21) | 0.92 (0.74, 1.14) |
| Black (*n*=171 329) | 1.00 (referent) | 0.87 (0.81, 0.94) | 0.89 (0.82, 0.96) | 0.99 (0.89, 1.10) |
| Asian (*n*=19 638) | 1.00 (referent) | 0.87 (0.70, 1.09) | 1.06 (0.75, 1.48) | 0.96 (0.61, 1.53) |
| Native American (*n*=7554) | 1.00 (referent) | 0.90 (0.69, 1.17) | 0.88 (0.69, 1.11) | 1.27 (1.01, 1.59) |

Hazard ratio (95% confidence interval), adjusted for age, gender, diabetes, cardiac disease, peripheral vascular disease, stroke, smoking at the initiation of dialysis, modality at 90 days, and zip code median per capita income and percent residents >25 years with a high school diploma.

**Table 4 | Facility characteristics and outcomes by location**

| | Urban (*n*=3103) | Large rural (*n*=627) | Small rural (*n*=497) | Small remote rural (*n*=136) | *P* for trend |
|---|---|---|---|---|---|
| Mean number of stations (±s.d.) | 19±18.7 | 14.8±6.6 | 12.6±5.1 | 11.2±4.7 | <0.001 |
| Peritoneal dialysis (%) | 50.4 | 40.8 | 26.0 | 19.9 | <0.001 |
| Home hemodialysis training (%) | 14.0 | 11.2 | 4.4 | 3.7 | <0.001 |
| Late shift (%) | 24.5 | 13.1 | 3.6 | 5.9 | <0.001 |
| For profit (%) | 79.0 | 76.5 | 72.4 | 69.9 | 0.001 |
| *Ownership* | | | | | |
| Independent (%) | 21.4 | 26.5 | 25.8 | 30.1 | 0.030 |
| Small chain (%) | 14.1 | 11.6 | 11.3 | 14.7 | 0.14 |
| Large chain (%) | 64.3 | 61.4 | 62.6 | 54.4 | <0.001 |
| Government (%) | 0.3 | 0.5 | 0.4 | 0 | 0.99 |
| Patients reaching target hematocrit (%) | 88.6 | 89.2 | 89.3 | 87.6 | 0.25 |
| Patients reaching target urea reduction ratio (%) | 91.2 | 92.5 | 92.9 | 92.6 | <0.001 |
| *Survival category* | | | | | |
| Better than expected (%) | 2.4 | 3.1 | 2.5 | 2.7 | 0.65 |
| As expected (%) | 92.7 | 94.5 | 95.3 | 95.6 | 0.012 |
| Worse than expected (%) | 4.9 | 2.4 | 2.3 | 1.8 | 0.001 |

groups was widest in rural areas. Rural non-Hispanic white patients were more likely, and rural black patients less likely to be transplanted than their urban counterparts. In fact, black patients living in small rural areas had lower transplant rates than any other group. Interestingly, adjusted time to transplant was shorter among Native American patients living in remote small rural areas than for urban Native American patients, although transplant rates were still low for this group.

Although more than one-fifth of incident dialysis patients in the US live in rural areas, rural location has been considered in only a small number of studies of dialysis patient outcomes. O'Riordan *et al.*[7] compared dialysis patient mortality by health authority type in the United Kingdom and found that mortality was lowest for patients living in urban and rural health authorities and highest for those living in mining or industrial health authorities. A study specifically examining dialysis care among patients living in rural Scotland reported exceedingly long travel times for rural dialysis recipients and advocated greater use of home-based therapies.[8]

Transplantation rates in rural areas probably reflect a complex interplay of different factors including access to an urban transplant center, desire, and need for an alternative to center hemodialysis among patients living far from a dialysis center, unmeasured cultural and socio-economic characteristics of rural compared with urban residents, differences in nephrology referral before the onset of ESRD and larger-scale regional variations in access to transplantation. The most striking feature in the present analysis was the pronounced urban–rural differences in time to transplant between non-Hispanic white and black patients. Low transplantation rates among black patients in the US have been well documented.[9–12] Racial disparities in access to transplantation appear to exist at the level of patient preferences, access to the transplant waiting list and movement up the transplant waiting list.[9–11] However, these studies have generally not distinguished between urban and rural black patients. Regardless of the reasons for low transplant rates among rural black patients, our findings identify this group as a potential target for efforts to improve access to kidney transplantation among black patients.

As most minority racial/ethnic groups are clustered in discrete regions of the country, the impact of rural residence on time to transplant in these groups must be viewed in the wider context of known regional variations in transplantation rates (www.usrds.org). Thus, for example, low transplant rates among rural black patients (who are concentrated in the South) must be viewed in the context of low overall transplant rates in the South (www.usrds.org).

The independent contribution of rural residence to low rates of transplantation among Native American patients has not been previously examined. However, it has been suggested that coordination of care over large distances may be an important barrier to transplantation among Native American patients.[13–16] Surprisingly, although transplant rates among Native American patients were low across the urban–rural spectrum, we found lower rates in small rural areas than in remote small rural areas. In fact, after adjustment for patient characteristics and area socioeconomic characteristics, Native American patients living in remote small rural areas were more likely than their urban counterparts to receive a transplant. This may reflect the unusual situation where some remote Native American communities have a sufficiently high prevalence of ESRD to support a dialysis unit.[14–18]

Although home-based therapies have theoretical advantages for patients living in remote areas[19,20] and increased travel time is associated with the use of peritoneal dialysis,[21,22] our analysis demonstrated high rates of in-center dialysis across the urban–rural spectrum. Even in remote small rural areas, in-center hemodialysis was the dominant mode of delivery. Paradoxically, rural dialysis facilities were less, rather than more, likely than urban facilities to offer peritoneal dialysis or home hemodialysis training, perhaps reflecting the specialized nature of these services. Certainly, high rates of center hemodialysis even in remote small rural areas of the US may reflect the older age and greater burden of comorbid conditions that preclude home-based therapies among rural dialysis patients.[22,23] However, modifiable factors known to impact the use of peritoneal dialysis such as lack of predialysis education and a scarcity of dialysis units providing peritoneal dialysis may also be important.[24,25] Further study is thus needed to determine whether modality choice is limited in rural areas.

A limitation of the present study is that we were not able to link patient level and dialysis unit level data using available data sources. We were thus unable to determine which patients were receiving dialysis at a rural facility, or travel time to dialysis for each patient. It is therefore unclear from this analysis as to what extent observed differences in patient survival and time to transplant are explained by facility differences rather than factors related to where patients live. It is also possible that our results may reflect residual confounding by severity of recorded comorbid conditions or the presence of unrecorded comorbid conditions. In addition, this is a cross-sectional study and thus these analyses are limited to the impact of rural residence at 90 days after the initiation of dialysis, although it is reassuring that sensitivity analyses examining the impact of rural residence at the initiation of dialysis did not differ materially from the primary analysis. We were also unable to examine the impact of rural residence on transplant referral at the facility level because Dialysis Facility Compare (DFC) does not report this information.

## CONCLUSIONS

Almost one-fourth of new dialysis patients live in rural areas. Despite differences in the structure of dialysis care (fewer for-profit facilities, fewer small chains, smaller dialysis units, fewer hemodialysis shifts) in rural areas, facilities in these areas performed at least as well as (if not better than) urban facilities. Furthermore, only among Hispanic white patients living in remote rural areas was mortality higher among rural than among urban residents. Among all other racial/ethnic groups, mortality among rural patients was either the same or lower than their urban counterparts.

However, black–white disparities in transplantation were more pronounced in rural than in urban areas and transplant rates were lower for rural black patients living in small rural areas than for any other group. Furthermore, use of home-based therapies was more common among rural than among urban residents, center hemodialysis remained the dominant modality even in remote small rural areas, and dialysis facilities in these areas were, paradoxically, least likely to support home-based therapies. These findings suggest that rural black patients should be targeted in policies intended to reduce racial disparities in transplantation and underline the need for further studies to understand whether rural dialysis patients have adequate access to home-based therapies.

## MATERIALS AND METHODS

### Data sources

Using the following data sources, we conducted parallel analyses to compare patient-level and dialysis facility-level characteristics and outcomes in rural and urban areas.

We examined patient characteristics and outcomes associated with rural location using data from the US Renal Data System, a comprehensive registry of all ESRD patients (www.usrds.org). Specifically, we used the PATIENTS, MEDEVID, RESIDENCE, and RXHIST60 files. The PATIENTS file contains information on date of first ESRD service, demographic information, date of first renal transplant, date of death and residence zip code at the initiation of ESRD care. The RESIDENCE file includes zip code of residence over time. The MEDEVID file includes information on comorbid conditions obtained from the Medical Evidence Form submitted at the onset of ESRD. The RXHIST60 file includes information on treatment modality over time. In addition, we obtained information on zip code median per capita income and percentage of residents 25 years and older with a high school diploma from the 2000 US census, in order to adjust for area-level socioeconomic characteristics.

As US Renal Data Service data do not include facility zip code, we used an alternate data source to examine dialysis unit characteristics using the Center for Medicare and Medicaid Studies' DFC database.[6] Facility level data from DFC could not be linked to the aforementioned patient-level data and thus patient and facility analyses were conducted separately. This is a publicly available source of current information on all Medicare-certified dialysis facilities. It grew out of the Balanced Budget Act of 1997, which directed the Center for Medicare and Medicaid Studies to implement a system to measure and report the quality of dialysis services under Medicare. DFC includes information on facility location, ownership, organization, services, and selected quality measures.

### Study population

We defined an incident cohort of all patients who initiated dialysis care between January 1, 1995 and December 31, 2002 and survived beyond 90 days. Patients who did not have a zip code of residence either at day 90 or at the initiation of ESRD, a medical evidence form and those for whom we could not determine the degree of rurality of their residence zip code were excluded. There were 709 519 incident ESRD patients during this time period. Among these, 106 917 died on or before day 90, and 17 886 underwent transplantation within the first 90 days of ESRD. Among the remaining patients, 459 patients were not having zip code information, 20 721 were not having a medical evidence form, and in 11 257 patients, zip code could not be linked to a rural–urban commuting area (RUCA) code. The analytic sample consisted of the remaining 552 279 patients.

Included in the facility sample were all Medicare-certified dialysis units listed in DFC for whom degree of rurality could be determined. There were 4440 facilities listed in DFC on December 29, 2004. Among these, 44 were located outside the US mainland and degree of rurality could not be determined for 33 of these facilities. Thus, the final sample consisted of 4363 facilities.

### Predictor variable

We used RUCA codes to determine the degree of rurality of each patient's residence 90 days after the initiation of chronic dialysis and of each dialysis facility based on zip code location. RUCA codes are assigned to census tracts based on measures of urbanization, population density and daily commuting (http://www.ers.usda.gov/briefing/Rurality/RuralUrbanCommutingAreas). A zip code approximation is available from the University of Washington (http://www.fammed.washington.edu/wwamirhrc/rucas/methods.html). In the present analysis, we categorized patients and dialysis units as urban, large rural, small rural, or remote small rural (Appendix A1).

### Covariates

Patient-level analyses were adjusted for patient age, sex and comorbid conditions at the initiation of dialysis and dialysis modality at 90 days after initiation. To accommodate a race interaction, survival analyses were stratified (rather than adjusted) for race/ethnicity (non-Hispanic white, Hispanic white, black, and Asian and Native American patients). The following comorbid conditions were included in adjusted analyses: diabetes, peripheral vascular disease, history of stroke, cardiac disease, and history of smoking. Patients were classified as having diabetes if diabetes was the cause of ESRD or if they were using insulin. Cardiac disease included those with a history of congestive heart failure, myocardial infarction, cardiac arrest, or ischemic heart disease.

At the facility level, we examined the association of RUCA category with facility characteristics available in the DFC database. These included mean number of dialysis stations, presence of a late shift (starting at 1700 hours or later), whether the facility offered peritoneal dialysis or home hemodialysis training, profit status (for-profit vs nonprofit), ownership (independent, state supported, or owned by a large ($\geqslant$100 facilities) or small chain ($<$100 facilities)). We also measured the association of RUCA code with facility-level performance measures reported in DFC, including the percentage of patients reaching a target hematocrit of 33% of higher, the percentage reaching a target urea reduction ratio of 65% or higher and the survival category of the facility based on the standard mortality ratio (better, worse, or as expected).

### Outcomes

Outcomes for patient level survival analyses were timed from day 91 of ESRD to death and first transplantation, respectively. Survival from day 91 is often used to analyze US Renal Data Service data because patients without Medicare coverage at the onset of ESRD do not become eligible until this time and thus data for these patients may be incomplete during the first 90 days (http://www.usrds.org/2004/rg/A_intro_sec_1_8.pdf.) In addition, mortality during the first 60 days of dialysis is much higher than it is thereafter, and selection of peritoneal and home hemodialysis may require a transition period after the initiation of dialysis. To estimate the impact of early mortality and modality switches, we conducted a sensitivity analysis using the alternate outcome of time from first ESRD service to death.

### Statistical analysis

Annualized mortality and transplant rates were calculated for each RUCA category by racial/ethnic group using Poisson regression. We compared patient and facility characteristics across RUCA categories using a test for linear trend. Patient survival and time to transplant by degree of rurality were examined using unadjusted and adjusted Cox's proportional-hazard analyses. For survival, patients were followed from day 91 to death or December 31, 2003. For time to transplant, patients were followed from day 91 to first transplant and were censored at the time of death. As described above, we conducted a sensitivity analysis using time from first ESRD service (day 1) to death. All analyses were conducted using Stata 7 (College Station, TX, USA). Analyses of survival time and time to transplant were stratified by race/ethnicity because there were statistically significant interactions with race/ethnicity in each model, and race/ethnicity was a major effect modifier in both analyses. The relatively small number of patients for whom race was unknown or who were classified as 'other race' ($n = 6804$) were not included in stratified survival analyses.

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## Appendix A1

The RUCA codes classify the US census tracts using measures of population density, urbanization and daily commuting. Based on 2000 Census definitions, urban areas are of two types – urbanized areas and urban clusters (http://www.ers.usda.gov/Briefing/Rurality/WhatisRural). In general, an urban area must have a core with a population density of 1000 persons per square mile and may contain adjoining territory with at least 500 persons per square mile. RUCA codes distinguish between urbanized areas (50 000 or more persons), large urban clusters (10 000–49 999 persons), and small urban clusters (2500–9999 persons) and rural areas (nonurban areas with $<2500$ persons) (http://www.ers.usda.gov/Data/RuralUrbanCommutingAreaCodes). In the classification scheme used here, urban areas include both urbanized areas, and all other areas (small and large urban clusters and rural areas) in which $\geqslant 30\%$ of inhabitants commute on a daily basis to an urban area.[5]

**Table A1 | Classification of rural urban commuting areas**

| | Urban | Large rural | Small rural | Remote small rural |
|---|---|---|---|---|
| Urbanized area or area with $\geqslant 30\%$ daily commuting to an urbanized area | x | | | |
| Urban cluster with $<30\%$ commuting to an urbanized area | | x | | |
| Small urban cluster with $<30\%$ commuting to an urbanized area | | | x | |
| Rural area with $<30\%$ commuting to an urbanized area | | | | x |